Texas Corn Producer Board Research Report – December 2016 (#M1501711)

Title: Corn hybrid and population effects on grain yield losses during the early reproductive growth stage

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Research rationale and value

In the Texas Panhandle, peak irrigation requirements for corn typically coincide with the critical reproductive phases from fertilization through early kernel development. For "average" weather conditions in Bushland, TX, irrigation required by corn during this period (in addition to that supplied by rainfall and available stored water) is 0.22 inches/day (4.1 gpm/acre) although peak irrigation requirements can be as high as 0.40 inches/day (7.9 gpm/acre). Failure to meet the water requirements of corn during fertilization and early kernel development is likely the predominant abiotic factor responsible for sub-optimal grain yield and water use efficiencies of corn in the region. Assessing the magnitude of these yield reductions is the first step in evaluating corn production risks and making informed production decisions on planted acreage.

Water stress during the V12 through R2 stages can reduce yield potential primarily through asynchrony in fertilization (esp. reduced silk elongation rate) and abortion of the fertilized ovule both of which reduce kernel set. Recently developed cultivars exhibit some drought tolerance through a shortened anthesis to silking interval and rooting morphologies that can extract a greater proportion of soil water. Quantification of how hybrids with these traits respond to water stress and influence crop water use, water use efficiency, kernel set and other yield components are important considerations for irrigation management that have not been fully evaluated under Texas Panhandle growing conditions.

Methods

Research was conducted at the USDA-Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, Texas, USA (35°11'N, 102°5'W; 1170 m elevation). Experimental plots established on a 90- by 109-m field on Pullman clay loam (Fine, mixed, superactive, thermic Torrertic Paleustoll) with < 1% slope in a randomized complete block design. Plots were planted on May 12, 2016 under conventional tillage with Bicep II as a pre-plant herbicide (Atrazine + Metolachlor). Plots were 6 rows x 100 feet with three replications. Experimental plots were sampled and analyzed for fertility requirements in April for a yield goal of 250 bu/ac yield goal; 10-29-0-3 was applied at planting at a rate of 70 lbs P_2O_5/ac, 27.3 lbs N/ac and 9.3 lbs S/ac. Subsequent nitrogen applications have been applied through the sprinkler in increments of 50 lbs N/ac at V3, V6, V9, V12 and R1. Irrigation was applied with a three-span, lateral-move sprinkler system (Model 6000, Valmont Irrigation, Valley, NE). Drop hoses spaced 1.5-m apart were equipped with No. 15 low drift nozzles (0.32 L s-1) (Senninger Irrigation, Inc., Clermont, FL) at 0.5-m above ground surface, convex-medium grooved spray pads, and 68.9 kPa pressure regulators. Irrigation was scheduled based on weekly measurements of precipitation plus change in stored soil water within the rooting zone (0 to 1.6m). Soil water content was determined using a neutron moisture gage (model 503DR, InstroTek, Inc., Raleigh, NC) from 0.1- to 2.3-m depth in 0.2-m increments at weekly intervals throughout the growing season.

Micrometerological variables were monitored using a datalogger (model CR23X, Campbell Scientific, Inc., Logan, UT) and environmental instrumentation located centrally within the experimental field. Measurements were recorded at 0.25-h intervals and included ambient air temperature and relative humidity (model HMP45C Temperature and Humidity Probe, Vaisala Inc., Helsinki, Finland), wind velocity (model 014A wind sensor, MET-ONE Instruments, Inc, Grants Pass, OR), and total global irradiance (model LI-200SA pyranometer, Li-Cor Biosciences, Lincoln, NE) all at 2 m above the surface. Precipitation was measured using a tipping bucket rain gage (TE525M, Texas Electronics, Dallas, TX) and incoming and reflected short and longwave radiation in 2010 and 2012 (models CM14 albedometer and CGR3 pyrgeometer, Kipp and Zonen, Delft, Netherlands), and net radiation (model Q*7.1 Net Radiometer, REBS, Bellevue, WA) were measured at 0.5 to 1.0 m above the canopy. Reference evapotranspiration (ET0) was calculated from monitored variables using the ASCE standardized reference evapotranspiration equation at hourly intervals (Allen et al., 2005). Green leaf area index (*LAI*) was determined by sampling three representative corn plants within each experimental plot. Senesced leaved were removed, and green leaf area was measured using a leaf area meter (model LI-3100, LICOR, Inc., Lincoln, NE).

This report includes final yield and crop water use data. <u>Relative humidity, leaf area and aboveground biomass throughout the season, aboveground biomass at harvest and harvest index, stem carbohydrates (3 sampling dates), kernel fill on ears and ear development during the early reproductive stages, and mean kernel mass and kernel mass per ear will be provided in a separate report upon completion of data analyses.</u>

In-season precipitation was 9.9 inches. In-season irrigation is 23.3 inches for the 1 inch/3 day treatment and 14.6 inches for the 1 inch/6 day treatment. Daily potential evapotranspiration (ET_o) was calculated throughout the growing season from in-field meteorological data. Targeted planting populations were 26,000 and 36,000 plants/acre. Sampled populations at harvest were 32,000 and 40,000 plants/acre. Plots (Hand-samples and large plot sub-samples) were harvested on September 29, 2016:

1. Four hand sampled subplots per replication with an area of 1 m x 2 rows. Both aboveground biomass and grain were sampled from these plots.

2. Two (large) subplots per replication with an area of 20 foot x 2 rows. Only grain was sampled from these plots.

Results

During the growing season, there were no significant differences in crop water use between cultivar and population, which averaged 861 and 657 mm for the high and low irrigation rate (Table 2). Maximum rooting depth root (1.4 to 1.6 m; 4.5 to 5.1 ft.) was achieved by approximately day of year 203 (VT stage). At day of year 230 (August 17, 2016), soil water extraction since day 167 (June 15, 2016) averaged 25.2 mm (0.99 inch) and 90.0 mm (3.54 inch) for the high and low irrigation treatments, respectively. Rooting depth was greater under the low irrigation rate but this additional depth resulted in a negligible increase (< 5 mm) in soil water extraction. After day 230, significant precipitation events increased soil water storage in the profile so that change in soil water for the entire growing season was small (~ 1 inch) under both irrigation treatments (Table 2).

At the high irrigation level, grain yield averaged 252 bu and was not influenced by cultivar or plant population. At the low irrigation level, grain yield averaged 83 bu and, at these low irrigation levels, average grain yield was 64% greater at the lower plant population compared with the high plant population. At high plant populations, not all plants produced harvestable ears at the low irrigation rate (Fig. 2). In addition, many of the ears at the high population and low irrigation level were small or had many aborted kernels. A fraction of the yield reduction at low irrigation rates may be attributable to greater susceptibility of drought weakened plants to attack by corn earworm (*Helicoverpa zea*) and subsequent colonization by molds (principally *Penicillium* spp.).

Soil water stress for both irrigation treatments peaked at approximately day of year 209 (July 27, 2016) a few days prior to tasseling (VT). Depletion levels greater than about 28% indicate that the crop is undergoing water stress that will cause yield declines. At the higher irrigation rate, water stress occurred on a few days during late July that likely caused a small amount of grain yield reduction from full irrigation indicating that an irrigation capacity of 6.29 min^{-1} ac^{-1} was marginal for fully irrigated corn during <u>this</u> growing season. At the lower irrigation rate, the corn was under severe water stress beginning on V8 (day of year 177; June 25, 2016) and extending to day 243 (R5 – Dent stage). This early water stress during the vegetative stage was responsible for the small ear sizes at this low irrigation rate (Fig. 2).

At the low irrigation level and low plant population, P1151 and DKC62-98 outperformed the drought tolerant DKC62-27 cultivar. Based on the yield results during this season, drought tolerant cultivars did not exhibit any yield advantage at high or low irrigation rates in comparison to the “non-drought tolerant” cultivar. These results may diverge other cropping years and depends on the timing of the water stress during the season and the particular adaptability of each cultivar to continue to sustain yield at each of the physiological growth stages. Crop water use efficiencies averaged 1.83 kg m^{-3} at the high irrigation level (Table 2) which is considerably lower than the maximum achieved at the CPRL research station in 2014 (2.5 kg m^{-3}) in a year with relatively low crop water requirements and ideal growing conditions (Fig. 3).

The steep grain yield response of corn to water use for this growing season implies that at the capacity of 3.14 gal min^{-1} ac^{-1}, irrigating double the acreage would be insufficient to offset total yield obtained from concentrating irrigation. That is, these results show that 22% greater total harvested yield would be obtained by planting and irrigating only half the acreage at 6.28 gal min^{-1} ac^{-1}. The long-term USDA-ARS objective of this research in collaboration with Texas A&M AgriLife and other research stations in the southern US Great Plains is to determine optimal planted acreage and associated production risks for a given irrigation capacity to achieve the maximum harvested yield an/or profitability and the most efficient use of groundwater. Additionally, this research will aid produces in making in-season irrigation decisions based on pre-plant soil moisture.

Table 1. Large plot (20 ft x 2 rows) and hand sampled (1 m x 2 rows) grain yield for all treatment combinations of the study (grain weight adjusted to 15.5% moisture content).

Cultivar	Sampled Population	Irrigation Capacity	Large Plot Yield		Hand Sample Yield†		
	1000 Plants/ac	gal/min·ac	Mg/ha	lbs/acre	Mg/ha	lbs/acre	bu/acre
P1151	32	6.29	15.41	13746	15.70	14003	250.1
P1151	40	6.29	16.96	15128	16.93	15102	269.7
P1151	30	3.14	7.53	6717	7.23	6447	115.1
P1151	37	3.14	4.14	3693	4.02	3589	64.1
DKC62-27	32	6.29	16.03	14299	15.93	14216	253.8
DKC62-27	42	6.29	15.97	14245	14.18	12650	225.9
DKC62-27	31	3.14	4.87	4344	5.64	5034	89.9
DKC62-27	41	3.14	4.81	4291	3.78	3372	60.2
DKC62-98	33	6.29	15.55	13871	16.04	14308	255.5
DKC62-98	40	6.29	16.19	14441	15.94	14218	253.9
DKC62-98	33	3.14	6.48	5780	6.49	5787	103.3
DKC62-98	41	3.14	4.99	4451	3.99	3557	63.5

†Hand sampled grain yields are approximate only and based on an estimated moisture content.

Table 2. Irrigation depth, crop water use and grain water use efficiency for the treatment combinations. Growing season precipitation was 253 mm.

Cultivar	Sampled Population	Irrigation Capacity	Irrigation depth	Change Stored Soil Water	Crop Water Use		Water Use Efficiency	Irrigation Use Efficiency
	1000 Plants/ac	gal/min·ac	mm	mm	mm	inches	kg/m^3	kg/m^3
P1151	32	6.29	592	-20.4	864	34.0	1.82	2.65
P1151	40	6.29	592	-24.3	868	34.2	1.95	2.86
P1151	30	3.14	370	-31.6	654	25.8	1.10	1.95
P1151	37	3.14	370	-33.0	656	25.8	0.61	1.09
DKC62-27	32	6.29	592	-15.8	860	33.9	1.85	2.69
DKC62-27	42	6.29	592	-26.1	870	34.3	1.63	2.40
DKC62-27	31	3.14	370	-30.0	653	25.7	0.86	1.52
DKC62-27	41	3.14	370	-39.8	663	26.1	0.57	1.02
DKC62-98	33	6.29	592	-10.7	855	33.7	1.88	2.71
DKC62-98	40	6.29	592	-4.9	849	33.4	1.88	2.69
DKC62-98	33	3.14	370	-38.2	661	26.0	0.98	1.75
DKC62-98	41	3.14	370	-32.1	655	25.8	0.61	1.08

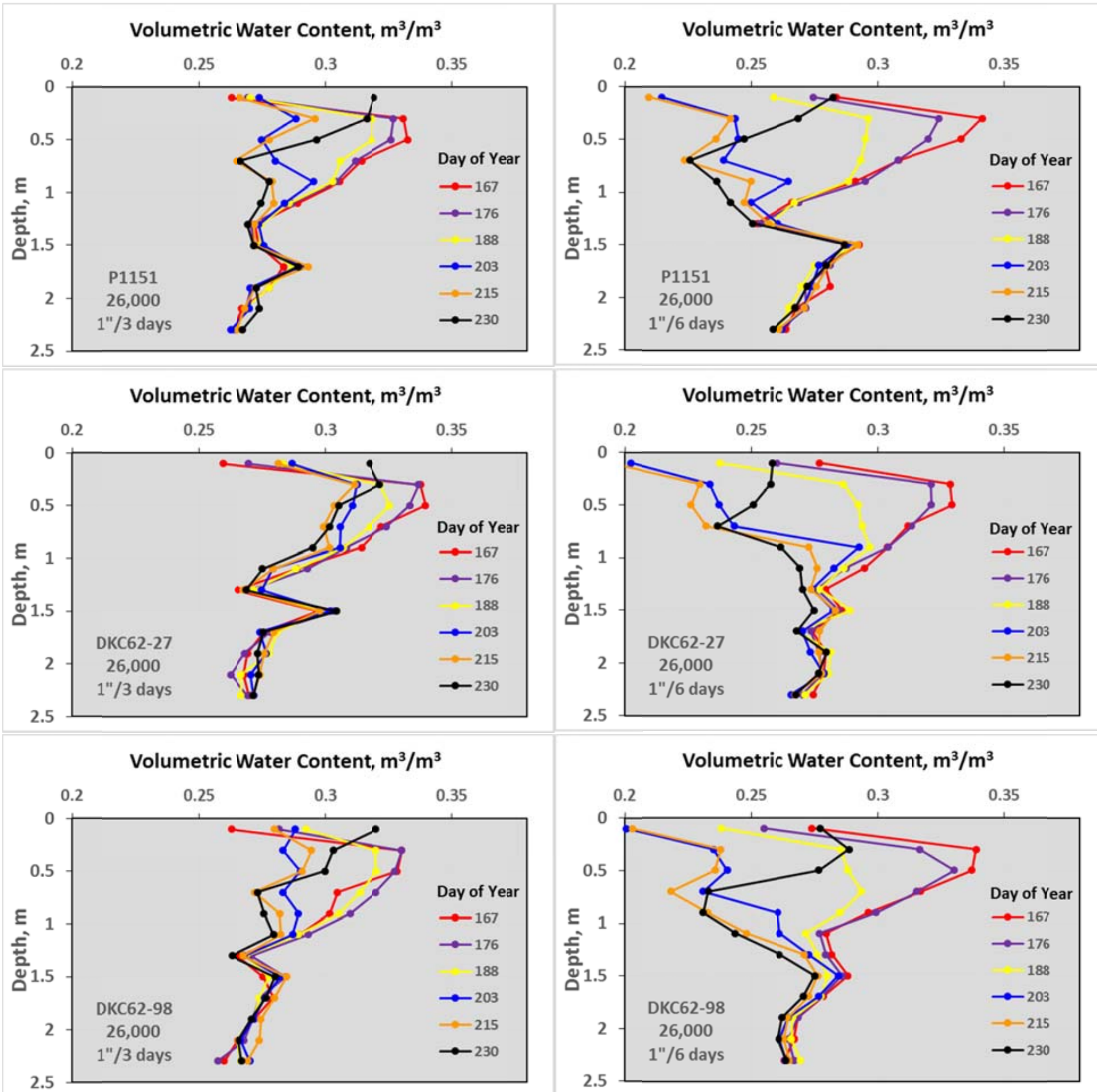

Figure 1. Soil water content profiles extending from 1 month after planting (V5) to late soft dough stage (R4) or day of year 167 to 230. Maximum root extension occurred at approximately day of year 203 (VT). Soil water extraction averaged 25.2 mm (0.99 inch) and 90.0 mm (3.54 inch) for the 6.29 and 3.14 gal min^{-1} $acre^{-1}$ irrigation capacities, respectively. Root extension was greater under the low irrigation rate but resulted in a negligible increase (< 5 mm) in soil water extraction.

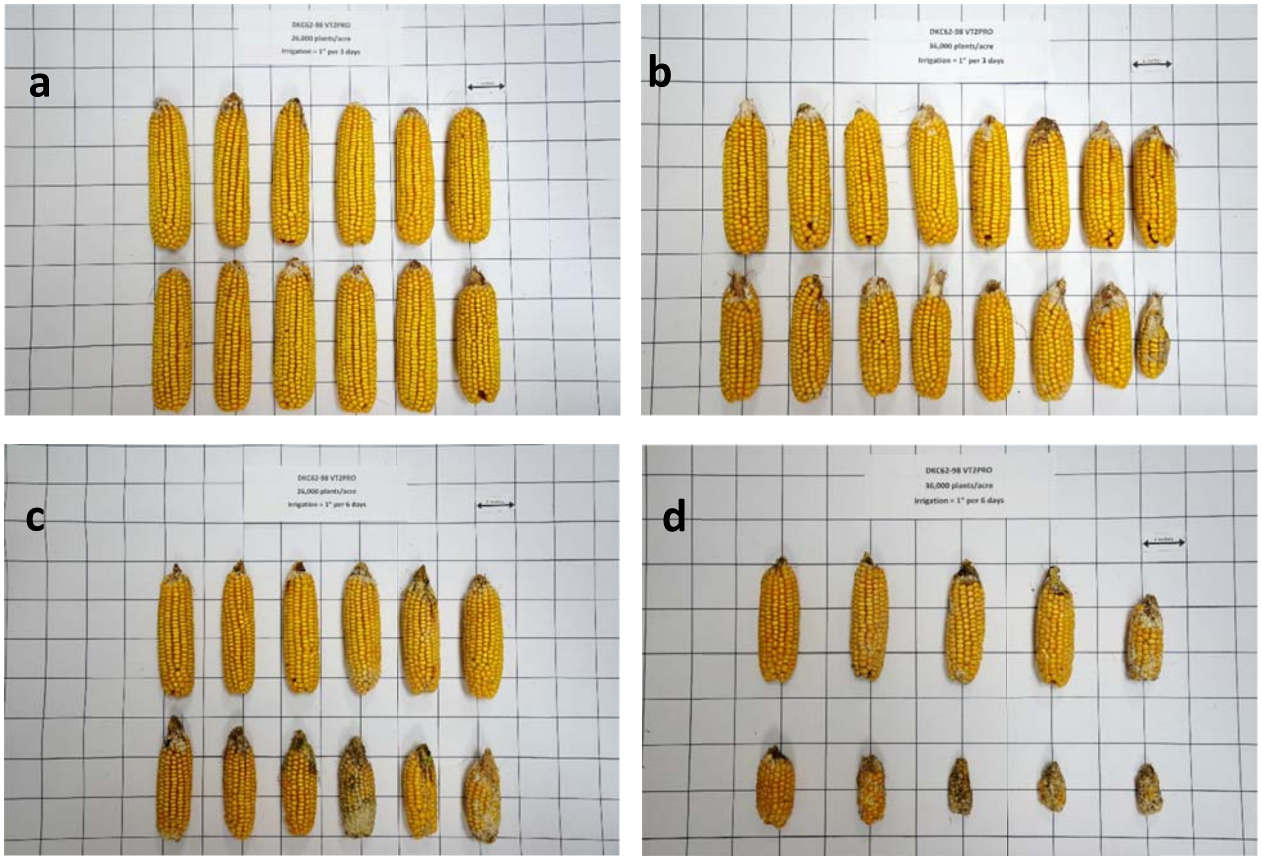

Fig 2. Ears from a representative 1 m x 2 row plot for the non-drought tolerant cultivar DKC62-98 VT2PRO at a) the 6.29 gal min^{-1} $acre^{-1}$ irrigation capacity at 26,000 plants/acre, b) 6.29 gal min^{-1} $acre^{-1}$ irrigation capacity at 36,000 plants/acre, c) 3.14 gal min^{-1} $acre^{-1}$ irrigation capacity at 26,000 plants/acre and d) 3.14 gal min^{-1} $acre^{-1}$ irrigation capacity at 36,000 plants/acre. Each square is 2 x 2 inches.

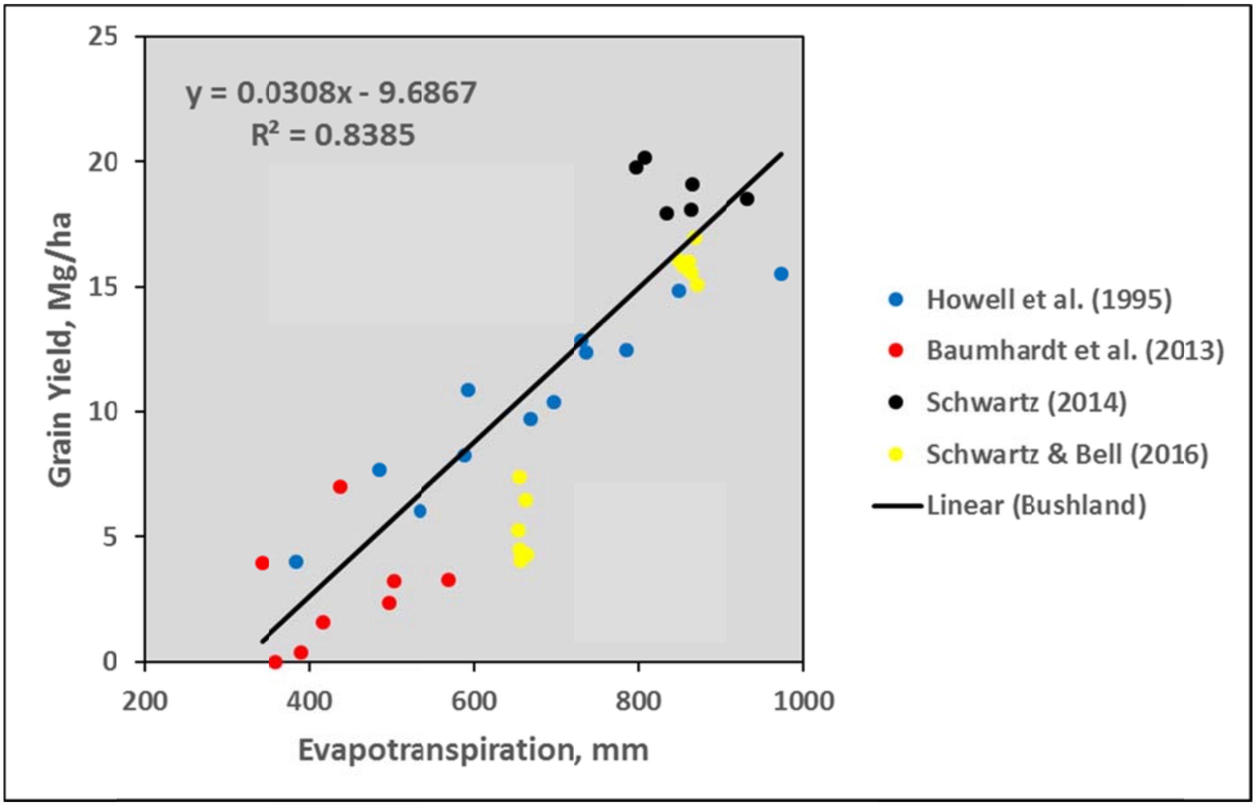

Figure 3. Corn yield response for CPRL, Bushland, TX (trend line) and the yield and water use obtained from this study in 2016.

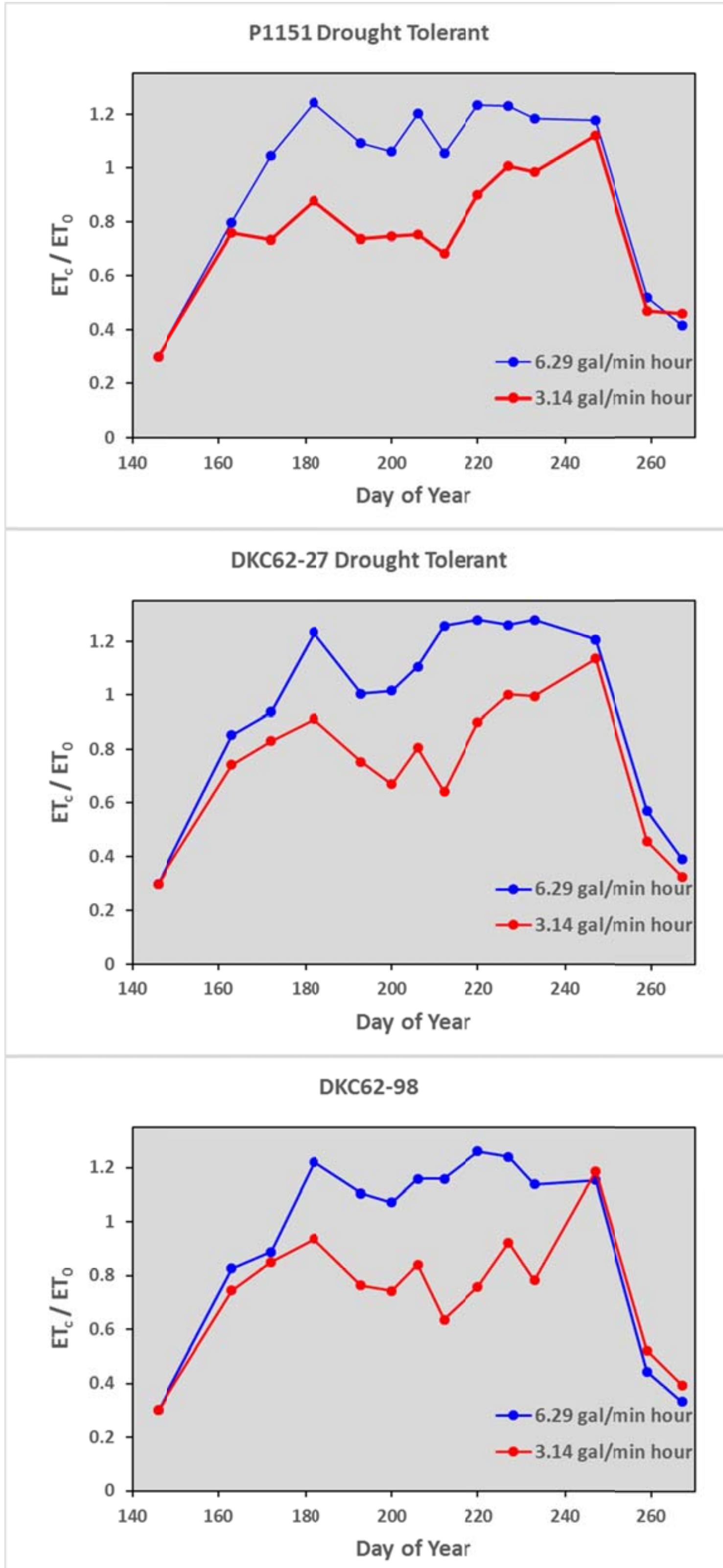

Fig. 4. Seasonal water use of corn as a fraction of potential ET for the three cultivars and two irrigation capacities. Data for each irrigation capacity represents pooled averaged for the two plant populations.

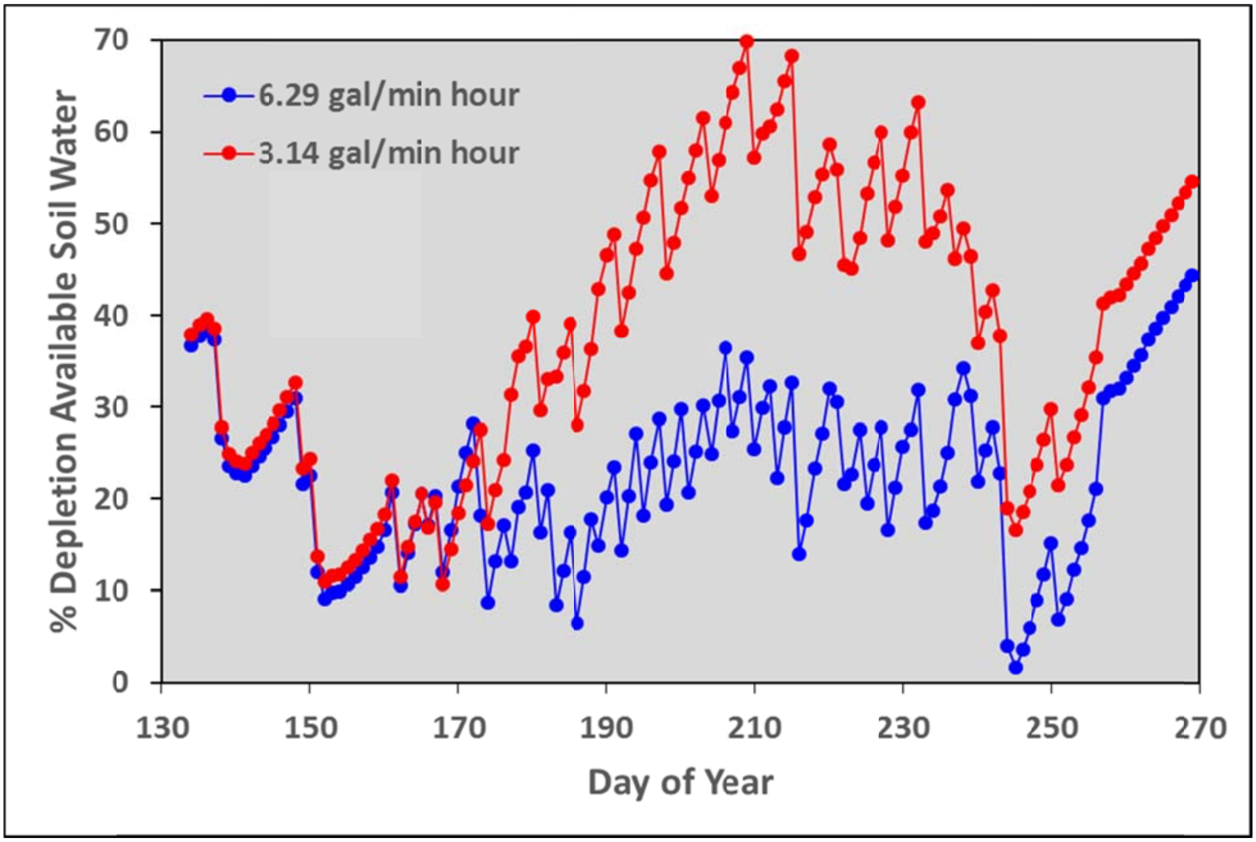

Fig. 5. Percent soil water depletion for the two irrigation capacities and averaged among cultivars and plant populations. The depletion levels were evaluated for a rooting depth of 1.4 m.